UPDATED FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND U.S. LANDFALL PROBABILITY FOR 2003

We anticipate a slightly above-average number of Atlantic basin tropical cyclones for the 2003 season and an increased probability of U.S. hurricane landfall. This is a downward adjustment from our prior 2003 forecasts.

(as of 6 August 2003)

This forecast is based on new research by the authors,
along with current meteorological information through July 2003

By

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with special assistance from William Thorson[4] and Jason Connor[5]

[This forecast as well as past forecasts and verifications are available via the World Wide Web: http://typhoon.atmos.colostate.edu/forecasts/index.html] - also,

Brad Bohlander and Thomas Milligan, Colorado State University Media Representatives, (970-491-6432) are available to answer various questions about this forecast.

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2003

Forecast Parameter and 1950-2000 Climatology (in parentheses)	6 December 2002	Update 4 April 2003	Update 30 May 2003	Update 6 Aug 2003
Named Storms (NS) (9.6)	12	12	14	14
Named Storm Days (NSD) (49.1)	65	65	70	60
Hurricanes (H)(5.9)	8	8	8	8
Hurricane Days (HD)(24.5)	35	35	35	25
Intense Hurricanes (IH) (2.3)	3	3	3	3
Intense Hurricane Days (IHD)(5.0)	8	8	8	5
Hurricane Destruction Potential (HDP) (72.7)	100	100	100	80
Net Tropical Cyclone Activity (NTC)(100%)	140	140	145	120

Later seasonal forecast updates and summaries will be issued on 3 September and 2 October 2003

PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL IN EACH OF THE FOLLOWING COASTAL AREAS:

1) Entire U.S. coastline - 64% (average for last century is 52%)

2) U.S. East Coast Including the Florida Peninsula - 43% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 36% (average for last century is 30%)

4) Expected above-average major hurricane landfall risk in the Caribbean

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DISTINCTION BETWEEN CSU SEASONAL HURRICANE FORECASTS AND THOSE ISSUED BY NOAA

Seasonal hurricane forecasts have now been issued for 20 years by the tropical meteorology research group of Prof. William Gray of the Department of Atmospheric Science, Colorado State University (CSU). The forecasts, which are issued in December of the prior year, and in early April, June, August and September of the current year, have steadily improved through continuing research. These forecasts now include predictions of net Atlantic basin tropical cyclone activity and U.S. and Caribbean hurricane landfall probabilities for seasonal as well as individual monthly periods.

The National Oceanic and Atmospheric Administration (NOAA) has also recently begun to issue Atlantic basin seasonal hurricane forecasts. The NOAA forecasts are independent of our CSU forecasts although they utilize prior CSU research augmented by their own insights. The NOAA and the CSU forecasts will typically differ in some aspects and details. Chris Landsea and Eric Blake, former CSU project members presently employed by NOAA, are making important contributions to both forecasts.

Specific differences between the CSU and the NOAA forecasts include:

1. CSU's forecasts give specific numbers rather than the range of numbers that the NOAA forecast gives.
2. CSU's forecasts are more quantitative than NOAA's. NOAA has yet to show a quantitative basis for their forecast skill in long period hindcasting statistics.
3. CSU issues four updated forecasts a year, NOAA only issues one.
4. CSU issues quantitative U.S. hurricane landfall probability forecasts - NOAA does not.
5. CSU makes individual monthly forecasts (August, September, etc.) - NOAA does not. This year we will issue our first October forecast.
6. NOAA's forecasts make extensive use of CSU's prior early December and early April seasonal forecasts and of two of Gray's ex-students (Christopher Landsea and Eric Blake) as important sources to their mid-May and mid-August forecasts.
7. This is our 20th year of making and verifying these forecasts. We have a quantitative skill and verification that NOAA has yet to demonstrate over a significant number of years.

NOTE ON THE CONTINUATION AND IMPROVEMENT OF CSU FORECASTS

The federal agencies of NOAA, FEMA and ONR who are charged with funding this type of forecasting research have declined support. The majority of the financial backing of these CSU hurricane forecasts in recent years has come from the research foundations of the insurance groups of the United Services Automobile Association (USAA - $300K over four years and State Farm - $375K over three years). We will always be grateful for their past financial backing, but these two insurance groups are not continuing their support any longer. They have given more than their fair share of support for the insurance industry. We must find other funding to continue issuing hurricane forecasts and to undertake the background research necessary to sustain them. It is hoped that other private or government groups who would like to see our hurricane forecasts continue provide us with financial help.

DEFINITIONS

ABSTRACT

Information obtained through July 2003 indicates that after 1 August, the 2003 Atlantic hurricane season will not be as active as previously indicated by our 30 May seasonal forecast. We estimate that 2003 will have the same number of named storms, hurricanes, and major hurricanes as our 30 May forecast, but the duration of the storms will be reduced. The number of storms has not been lowered because we have had an active early season of 4 named storms and 2 hurricanes. We foresee a seasonal total of 8 hurricanes (average is 5.9), 14 named storms (average is 9.6), 60 named storm days (average is 49), 25 hurricane days (average is 24.5), 3 intense (category 3-4-5) hurricanes (average is 2.3) and 5 intense hurricane days (average is 5.0). We expect Atlantic basin Net Tropical Cyclone (NTC) activity in 2003 to be about 120 percent of the long-term average. This is a reduction from our 30 May NTC forecast of 145. The probability of U.S. major hurricane landfall for the rest of the season is estimated to be about 12 percent above the long-period average. We also foresee an above-average probability of Caribbean basin landfall. This 6 August updated forecast is partly based on a newly-developed individual monthly statistical scheme that shows significant hindcast skill over the past 52 years. We also utilize an analog technique which selects prior years and prior months that have global conditions similar to this year. Our final forecast consists of a qualitative adjustment of these separate seasonal, monthly and analog methodologies. We will be issuing short updates to this forecast on 3 September and 2 October.

1 Introduction

This is the 20th year in which the first author has made forecasts of the coming season's Atlantic basin hurricane activity. Our Colorado State University research project has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This early August forecast is based on a new 52 year (1950-2001) seasonal and monthly hindcast scheme and an analog scheme that chooses prior years which had similar global atmospheric and oceanic conditions through July. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by our statistical analyses. These evolving forecast techniques are based on a variety of climate-related global and regional atmosphere and ocean precursor signals that in previous years have been shown to be related to the forthcoming Atlantic basin hurricane activity and landfall probability.

2 Forecast Methodology

We believe that seasonal forecasts must be based on methods showing significant hindcast skill in application to long periods of prior years. Most atmosphere-ocean circulation and energy exchange processes are too complicated to allow for skillful deterministic initial value seasonal and yearly prediction. It is only through hindcast studies that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided the atmosphere continues to behave in the future as it has in the past. Unlike initial value deterministic prediction, it is not necessary to fully understand all relevant atmospheric and oceanic processes to issue a skillful statistical forecast. One can use prior empirical associations without understanding all of the physical linkages and processes which are involved.

The last few years have seen tremendous growth in the accessibility of global atmospheric data on the Internet. An example of this accessibility is the NOAA/NCEP reanalysis which archives historical atmospheric and ocean surface data and makes this data easily available. Other cooperative research groups are developing similar reanalysis products. Many of these reanalysis data sets are available from the late 1940s and offer exciting and unique opportunities for the development of new and skillful extended range empirical climate forecasts.

There is a great curiosity as to how active the coming hurricane season will be. Any forecast with reasonable physical linkages which has demonstrated hindcast skill above that of climatology is of interest to most residents of the southeast U.S. and the Caribbean. It is important that the public be informed as to what the current atmospheric and oceanic conditions suggest may occur in the coming hurricane season.

3 Earlier 1 August Statistical Hurricane Forecast Schemes

Our original early August seasonal hurricane forecast scheme was developed in the early 1990s (Gray et al. 1993) and demonstrated significant hindcast skill for the period of 1950-1991 (Gray et al. 1994). This scheme included measurements of West African rainfall as an important forecast input. A revised 1 August forecast scheme was developed in the mid-1990s. Both schemes did not have the advantage of the NOAA reanalysis products of the last 2-3 years.

Since the observed shift of Atlantic Ocean SST patterns in 1995 [and implied increase in the strength of the Atlantic Thermohaline Circulation (THC)], our earlier 1 August forecast schemes have consistently underpredicted Atlantic basin hurricane activity. This has caused us to turn more to our analog forecast methodology for our recent forecasts. The previously observed (1950-1994) strong association between West African rainfall and Atlantic hurricanes has not been reliable since 1994.

We still consult our earlier August forecast schemes to see what they predict. These two previous 1 August forecast schemes which use African rainfall activity indicate that 2003 seasonal NTC activity will be 78 and 93 percent of the average Atlantic basin season.

3.1 New 1 August Seasonal Forecast Scheme

Most reanalysis data sets are available from the late 1940s and offer exciting and unique opportunities for the development of new and more skillful extended range empirical climate forecasts. For example:

1. Our new scheme has been developed on 11 more years of hindcast data (1950-2001).

2. Our new scheme has been able to use the recently developed NOAA/NCEP reanalysis data that were not available to us at the time we developed our earlier scheme. The reanalysis has allowed us to more readily search for new forecast parameters.

Through extensive analyses of the recently available NOAA/NCEP reanalysis products, Phil Klotzbach of our forecast team has recently developed a new set of 1 August extended range predictors which shows superior hindcast skill over our previous 1 August forecast schemes. This new 1 August forecast scheme does not use West African rain as a predictor. No significant improvement in hindcast skill was achieved by adding June-July fields to the 1 June forecast, and therefore, the 1 August seasonal forecast uses the same predictors as the 1 June forecast.

The pool of seven predictors for this new extended range forecast is given and defined in Table 1. The location of each of these new predictors is shown in Fig. 1. Strong statistical relationships can be extracted via combinations of these predictive parameters (which are available by the end of May), and quite skillful Atlantic basin hurricane forecasts for the following summer and fall can be made if the atmosphere and ocean continue to behave in the future as they have during the hindcast period of 1950-2001. Full documentation of the skill of this forecast can be found in our 30 May 2003 seasonal forecast.

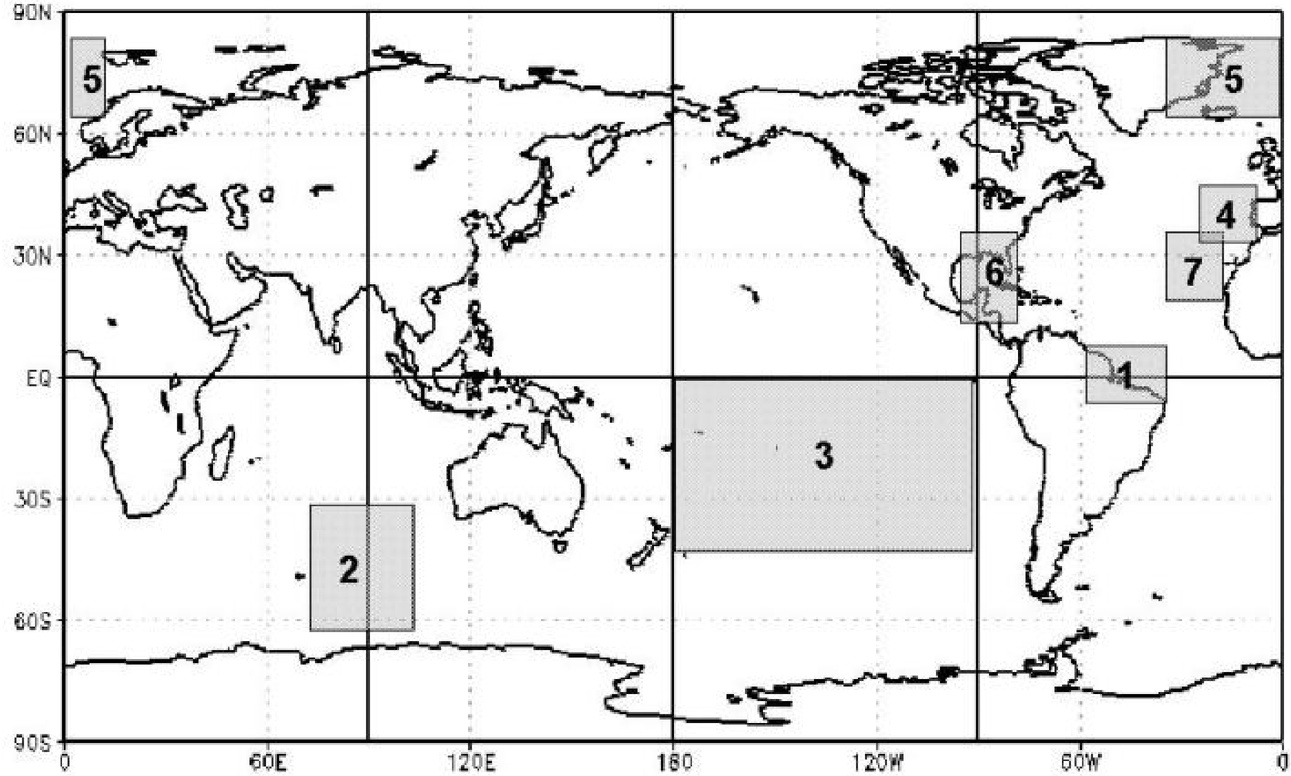

Figure 1: Location of predictors for our new 1 August forecast for the 2003 hurricane season.

Table 1: List of our new 1 August 2003 predictor set and their anomaly values for this year's hurricane activity. A plus (+) means that positive values of the parameter are associated with increased hurricane activity, and a minus (-) indicates that negative values of the parameter are associated with increased hurricane activity. Five of the seven values indicate increased hurricane activity for this year.

	2003 Observed Values
(1) - February 200 mb U Anomaly (5˙S-10˙N, 35-55˙W) (-)	+0.6 SD
(2) - February-March 200 MB V Anomaly (35-62.5˙S, 70-95˙E (-)	+0.5 SD
(3) - February SLPA (0-45˙S, 90-180˙W) (+)	+0.2 SD
(4) - February SSTA (35-50˙N, 10-30˙E) (+)	+0.7 SD
(5) - Previous November 500 mb Height Anomaly (67.5-85˙N, 10˙E-50˙W) (+)	+1.7 SD
(6) - Previous September-November SLP Anomaly (15-35˙N, 75-95˙W) (-)	-1.5 SD
(7) - May SSTA (20-40˙N, 15-30˙W) (+)	+0.5 SD

Table 2 shows our statistical forecast for the 2003 hurricane season and the comparison of this forecast with climatology (average season between 1950-2000). All our forecast parameters are expected to be above average. Brief descriptions of our new early August seasonal predictors are contained in our 30 May 2003 seasonal forecast, which is listed on our Colorado State University hurricane forecast web site.

Table 2: New 1 August statistical forecast for 2003.

Predictands and Climatology	Statistical Forecast Numbers
Named Storms (NS) - 9.2	11.2
Named Storm Days (NSD) - 49.1	55.1
Hurricanes (H) - 5.9	7.9
Hurricane Days (HD) - 24.5	32.2
Intense Hurricanes (IH) - 2.3	3.3
Intense Hurricane Days (IHD) - 5.0	6.2
Hurricane Destruction Potential (HDP) - 72.7	97
Net Tropical Cyclone Activity (NTC) - 100	133

4 Recently Developed Predictions of Individual Monthly Atlantic TC Activity for August, September, and October

A new aspect of our climate research is the development of TC activity predictions for individual months. There are often monthly periods within active and inactive Atlantic basin hurricane seasons which do not conform to the overall season. For example, 1961 was an active hurricane season (NTC of 222), but there was no TC activity during August; 1995 had 19 named storms, but only one named storm developed during a 30-day period during the peak of the hurricane season between 29 August and 27 September. By contrast, the inactive season of 1941 had only six named storms (average 9.3), but four of them developed during September. During the inactive 1968 hurricane season, three of the eight named storms formed in June (June average is 0.5).

We have started new research to see how well various sub-season or individual monthly trends of TC activity can be forecast. This effort has recently been documented in project reports by Eric Blake (2002) for August and Phil Klotzbach (2002) for September. These reports show that it is possible to develop a skillful predictive scheme for August-only and September-only Atlantic basin tropical cyclone activity. In addition, we are issuing our first October-only forecast this year. On average, August, September, and October have about 26%, 48%, and 17% of total NTC, respectively. Initial August-only forecasts have now been made by Blake for 2000-2002, and their verification looks promising.

It has been generally thought that it is more difficult to predict hurricane activity during shorter periods than to predict activity for the entire season. Despite the presumed inherent difficulties with these shorter period forecasts, Blake and Klotzbach have devised quite skillful August-only, September-only, and October-only prediction schemes based on 51 years (1950-2000) of hindcast testing using a statistically independent jackknife approach. Predictors are largely derived from June and July NCEP global reanalysis data but also include information from earlier in the year.

4.1 Independent August-Only Statistical Forecast

Figure 2 and Table 3 list the predictors used in the August-only hindcast (Blake 2002) for each of the nine different forecast parameters. The table also shows hindcast skill for the 51-year period 1950-2000, as well as the independent jackknife hindcast skill over this period. Table 4 gives the predictor values for August 2003. Table 5 gives our independent statistical prediction for August 2003. These predictors indicate below-average activity for August 2003.

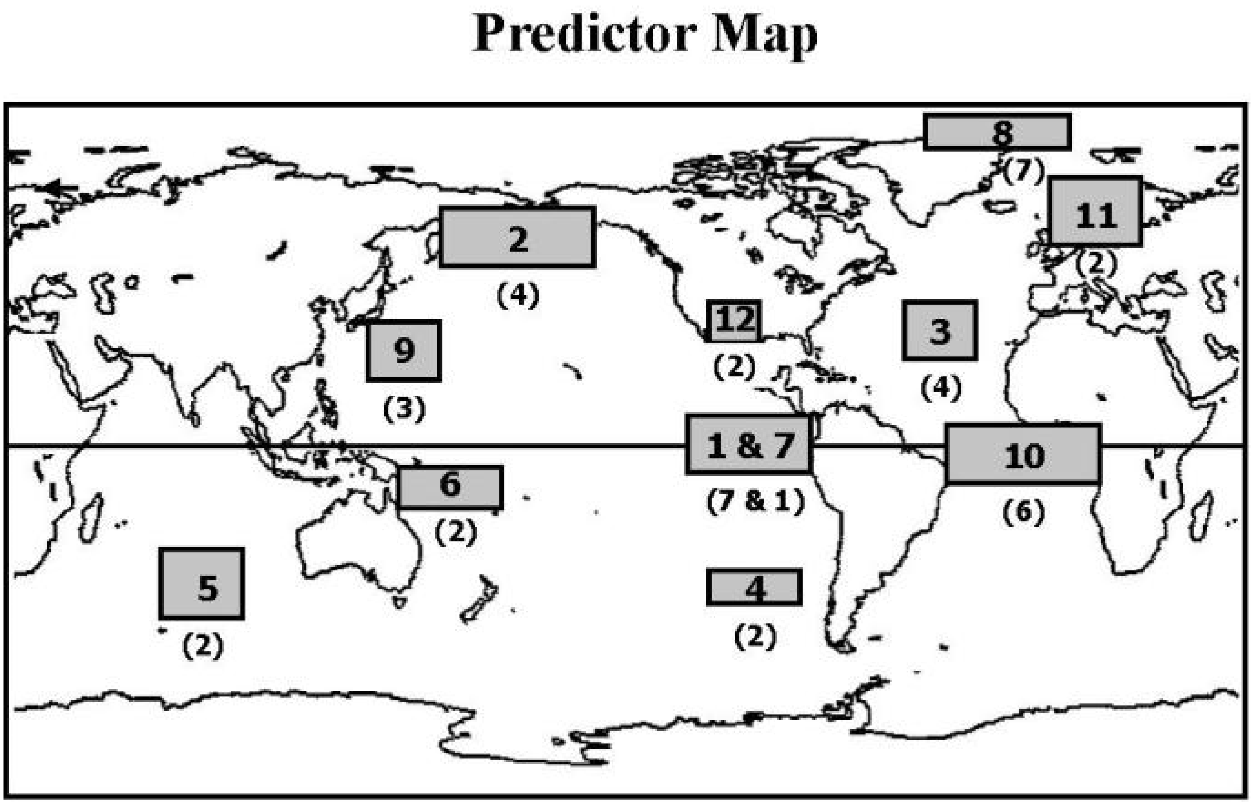

Figure 2: Global map showing locations of August-only TC predictors. Table 3 provides a listing and description of these predictors. The numbers in the boxes are keyed to descriptions in the bottom of Table 3. The numbers in parentheses beneath each box indicate how many predictive equations are used for each predictor.

Table 3: Listing of predictors chosen for each forecast parameter and the total hindcast variance explained by these predictors for the August-only forecast. The name and atmospheric parameter utilized in each predictor is given below - where the number for each is keyed to Fig. 2.

Forecast Parameter	No. of Predictors	Predictors Chosen from Table	Variability Explained by Hindcast (R^2) (1949-1999)	Likely Independent Forecast Skill (Jackknife)
NS	5	3, 6, 7, 9, 11	.55	.41
NSD	5	1, 2, 3, 8, 10	.71	.61
H	4	1, 2, 8, 10	.57	.47
HD	5	3, 4, 8, 9, 19	.69	.59
IH	5	1, 3, 5, 8, 12	.68	.59
IHD	5	1, 4, 5, 6, 9	.78	.72
NTC	5	1, 2, 8, 10, 12	.74	.66
TONS	4	1, 8, 10, 11	.68	.60
TOH	4	1, 2, 8, 10	.64	.56

1) Galapagos July 200 mb v, sign of correlation (-)
2) Bering Sea July SLP, sign of correlation (-)
3) Atlantic Ocean July SLP, sign of correlation (-)
4) SE Pacific July 200 mb u, sign of correlation (-)
5) S. Indian Ocean July 500 mb ht, sign of correlation (-)
6) Coral Sea July 200 mb u, sign of correlation (+)
7) Galapagos July 200 mb u, sign of correlation (-)
8) North Greenland June 200 mb u, sign of correlation (+)
9) Northwest Pacific June SLP, sign of correlation (+)
10) S. Atlantic Ocean April SLP, sign of correlation (-)
11) Scandinavia February SLP, sign of correlation (-)
12) SW USA January SLP, sign of correlation (-)

Table 4: August 2003 Predictor Values

Predictors	**2003 Observed Values**
Galapagos July 200 mb v, sign of correlation (-)	-0.7
Bering Sea July SLP, sign of correlation (-)	+1.9
Atlantic Ocean July SLP, sign of correlation (-)	+0.2
SE Pacific July 200 mb u, sign of correlation (-)	+0.5
S. Indian Ocean July 500 mb ht, sign of correlation (-)	+1.05
Coral Sea July 200 mb u, sign of correlation (+)	+0.5
Galapagos July 200 mb u, sign of correlation (-)	+0.1
North Greenland June 200 mb u, sign of correlation (+)	+1.9
Northwest Pacific June SLP, sign of correlation (+)	0.0
S. Atlantic Ocean April SLP, sign of correlation (-)	+1.5
Scandinavia February SLP, sign of correlation (-)	+1.0
SW USA January SLP, sign of correlation (-)	+1.25

Table 5: Independent August-only prediction of 2003 hurricane activity based on Blake (2002). August climatology is shown in parentheses.

	Statistical Model	**Qualitative Adjustment**
NS	2.51 (2.76)	3
NSD	7.31 (11.80)	8
H	0.68 (1.55)	1
HD	3.81 (5.67)	4
IH	0.63 (0.57)	1
IHD	0.42 (1.18)	0.5
NTC	17.91 (26.1)	22

4.2 Independent September-Only Statistical Forecast

Figure 3 and Table 6 portray and list our 1 August predictors for September-only activity for this year. The number of predictors used and individual parameter hindcast skill are given in Table 7. Table 8 gives the predictor values for September 2003. Table 9 gives our independent September statistical forecast and our adjusted statistical forecast.

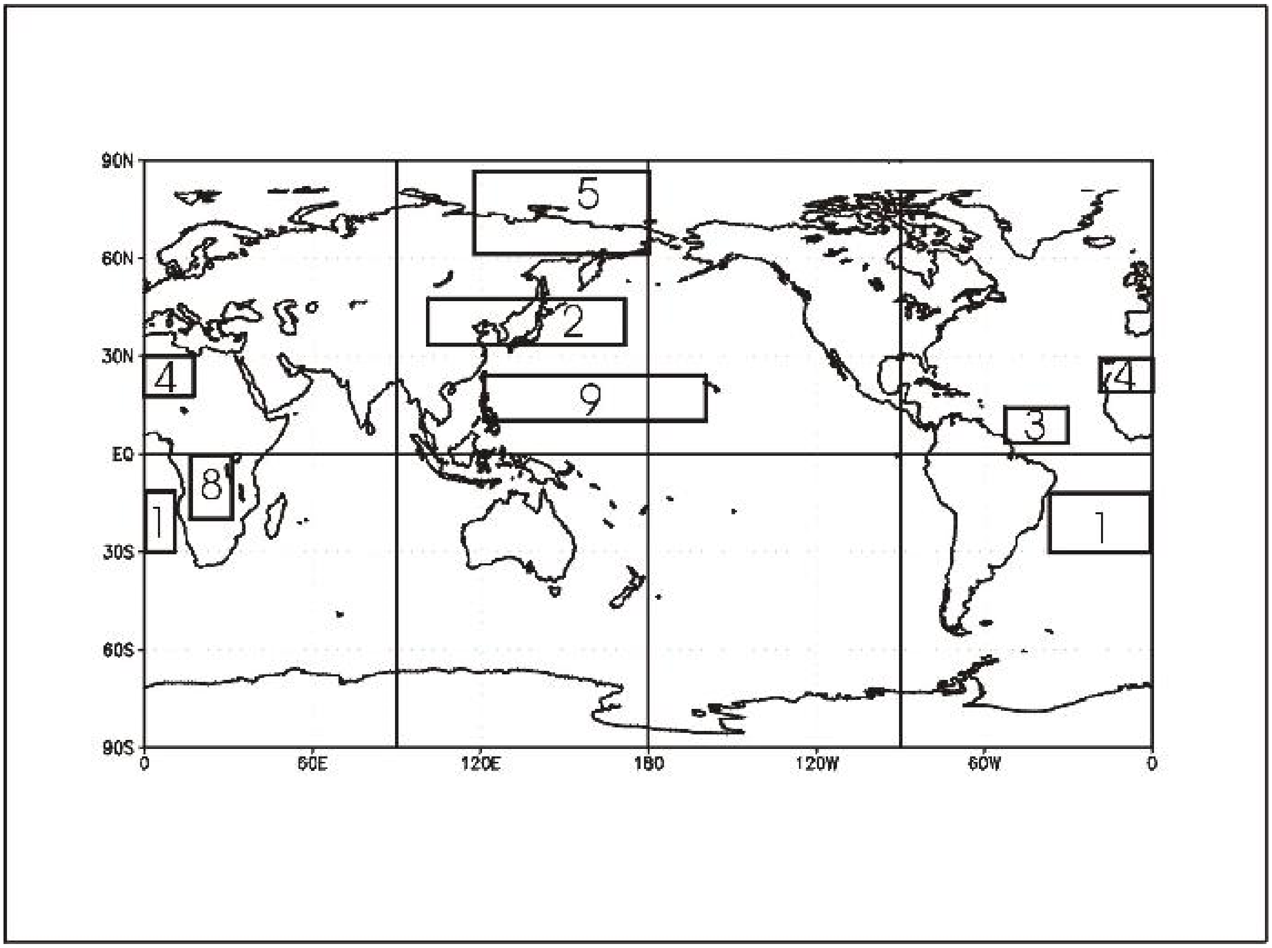

Figure 3: Predictors selected for the end of July forecast of September tropical cyclone activity. The numbers in each area are keyed to the description given in Table 6.

Table 6: Predictors selected for the end of July forecast of September tropical cyclone activity. The sign of the predictor associated with increased tropical cyclone activity is in parentheses. Note that predictors 6 and 7 are not used since they require August data.

Name of Predictor	Location	Equations Used
1) April 1000 mb U (-)	(12.5-30°S, 40°W-10°E)	IH
2) July 200 mb Geo Ht. (+)	(32-42°N, 100-160°E)	NS, NSD, H, HD, IH, TONS, TOH, NTC
3) July 1000 mb U (+)	(5-15°N, 30-50°W)	NS, NSD, H, HD, IH, IHD, TONS, TOH, NTC
4) Feb. 1000 mb U (-)	(20-30°N, 15°W-15°E)	NSD, HD, IHD, NTC
5) April 200 mb U (-)		NS, NSD, HD, IH, IHD, TONS, TOH, NTC

	(67.5-85°N, 110-180°E)	
8) May 200 mb V (+)	(0-20°S, 15-30°E)	NSD, H, HD
9) Jan-Feb 200 mb U (-)	(15-25°N, 120°E-160°W)	IH, IHD, TONS, TOH, NTC

Table 7: Variance (r^2) explained for each of the nine TC activity indices and aggregate NTC based on the 1 August hindcast of September tropical cyclone activity from 1950-2000.

Parameter	**Number of Predictors**	**Variance Explained**	**Jackknife Variance Explained**
NS	3	0.29	0.19
NSD	5	0.54	0.44
H	3	0.38	0.28
HD	5	0.60	0.51
IH	5	0.63	0.53
IHD	4	0.63	0.54
TONS	4	0.50	0.40
TOH	4	0.63	0.55
NTC	5	0.75	0.68
Aggregate NTC		0.80	

Table 8: September 2003 predictor values - the sign of the predictor associated with increased tropical cyclone activity is in parenthesis.

Predictor	**2003 Observed Values**
1) April 1000 mb U (12.5-30S, 40W-10E) (-):	+1.9 SD
2) July 200 mb Geopotential Height (32-42N,100-160E) (+):	-1.2 SD
3) July 1000 mb U (5-15N,30-50W) (+):	+0.1 SD
4) February 1000 mb U (20-30N, 15W-15E) (-):	+0.5 SD
5) April 200 mb U (67.5-85N, 110-180E) (-):	-0.4 SD
8) May 200 mb V (0-20S, 15-30E) (+):	-1.4 SD
9) January-February 200 mb U (15-25N, 120E-160W) (-):	+1.1 SD

Table 9: Independent 2003 September statistical forecast based on data through July 2003.

Statistical Forecast	**Adjusted Statistical Forecast**
NS: 3.1	NS: 4.0
H: 1.4	H: 2.0
IH: 0.3	IH: 1.0

NSD: 13.25	NSD: 14.0
HD: 6.00	HD: 6.0
IHD: 1.25	IHD: 1.25
NTC: 28.7	NTC: 33.0

Data available through the end of July indicates that September 2003 will be less active than normal. The most significant predictor, 1000 mb trade winds in the Atlantic (5-15°N, 30-50°W), is running about normal which indicates approximately average storm development due to average shear in the main development region. The other predictors are mostly negative. An updated September-only statistical forecast will be issued on 2 September. This early September forecast will have the advantage of August data.

4.3 Independent October-only Statistical Forecast

We are issuing our first monthly forecast for October-only tropical cyclone activity this year. Through examination of the NCEP/NCAR reanalysis, we have discovered four predictors that in combination explain about 50 percent of the October cross-validated variance in Net Tropical Cyclone activity for the hindcast period of 1950-2001. We are currently unable to find combinations of predictors that explain large amounts of variance for the individual tropical cyclone parameters (i.e., named storms, hurricane days, etc.). Therefore, our October forecast consists of predicting NTC and consequently increasing or decreasing October's values for the other parameters accordingly. For example, if October NTC was 150 percent of normal and a typical October had two named storms, we would forecast three named storms for October. The predictors utilized in our initial October prediction are displayed graphically in Figure 4, and their 2003 values are displayed in Table 10. Two of the four predictors are positive for storms, one is neutral, and one is weakly negative. Therefore, we are calling for a slightly above-average October with an NTC about 30 percent larger than the climatological average. In round numbers, we are forecasting 3 named storms, 2 hurricanes, 0 intense hurricanes and a NTC of 19 for October. Physical links between the predictors and October tropical cyclone activity follow:

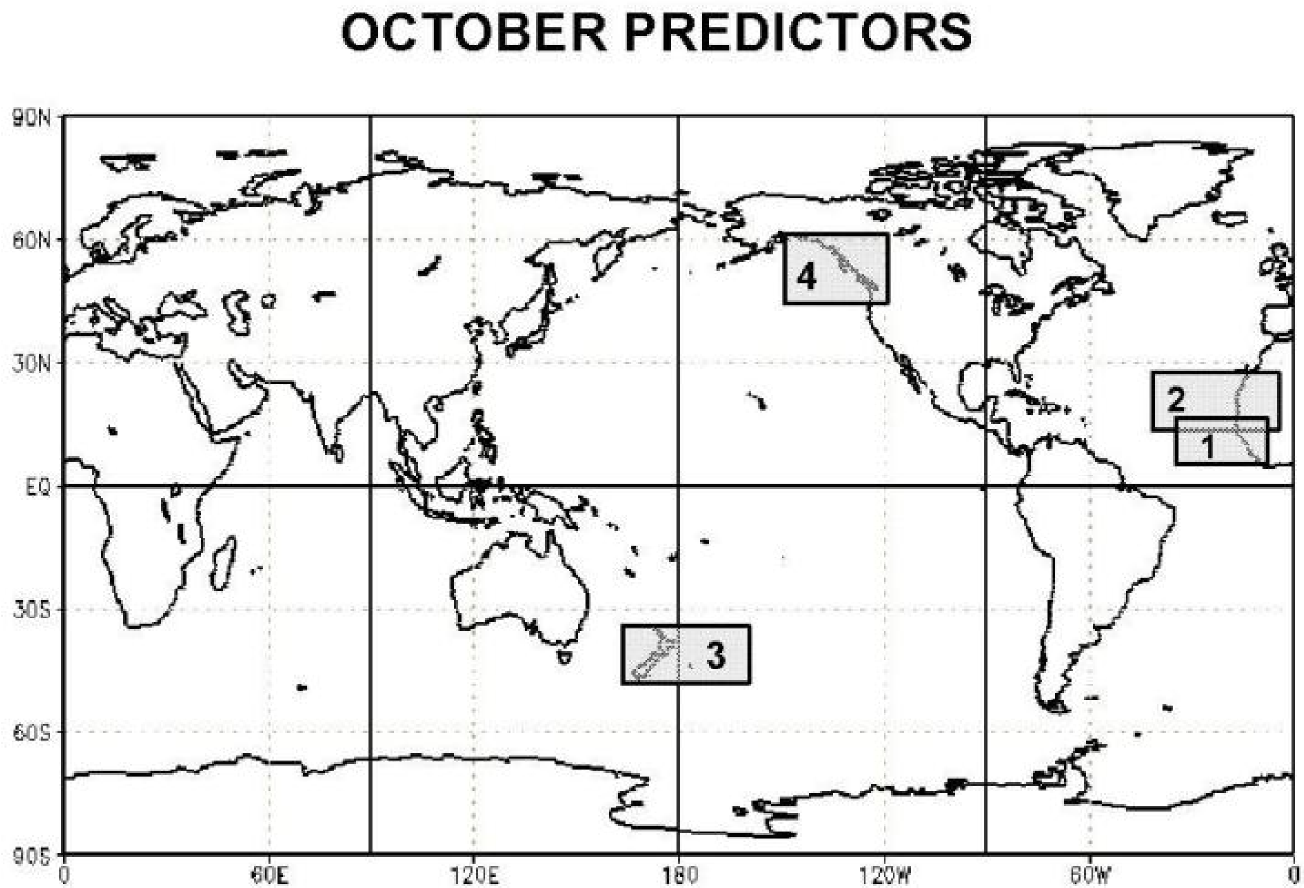

Figure 4: Location of 1 August predictors for October tropical cyclone activity.

Table 10: Predictors selected for the 1 August forecast of October tropical cyclone activity. The sign of predictors is associated with increased tropical cyclone activity.

Predictor	2003 Observed Values
1) June-July (10-25°N, 10-40°W) (-):	+0.1 SD
2) July 200 mb Geopotential Height (20-35°N,5-45°W) (+):	+1.0 SD
3) July 200 mb U (35-47.5°S,160°E-160°W) (+):	-0.3 SD
4) Previous November SLP (45-65°N, 115-145°W) (-):	-0.5 SD

4.4 Physical Association of October Forecast Parameters

1. June-July Sea Level Pressure (10-25°N, 10-40°W) (-)

   Low sea level pressure in June-July in this part of the subtropical Atlantic is the most important predictor for October tropical cyclone activity. Low pressure indicates that a weak subtropical ridge is present, trade winds are weaker, and consequently, due to an evaporation decrease, the tropical Atlantic is warmer than normal. On a climatological average, tropospheric vertical wind shear and sea level pressure are directly related. Lower than normal sea level pressure indicates that late-season tropical cyclones are more likely to occur due to a combination of reduced wind shear and a warm tropical Atlantic.

2. July 200 mb Geopotential Height (20-35°N, 5-45°W) (+)

   High heights in the northern subtropical Atlantic indicate that there is an increased height gradient between the tropical and subtropical Atlantic which decreases the area and strength of upper-level westerly winds. Stronger easterlies tend to persist throughout the remainder of the hurricane season thereby reducing vertical wind shear and providing more favorable conditions for October tropical cyclone development.

3. July 200 mb U (35-47.5°S, 160°E-160°W) (+)

   Increased upper-level westerlies near New Zealand indicate increased Southern Hemisphere winter baroclinicity which is typically associated with favorable conditions for tropical cyclones in the Atlantic. These conditions tend to persist through October, increasing the likelihood of late-season tropical cyclones.

4. Previous November SLP (45-65°N, 115-145°W) (-)

   Low sea level pressure in this area during November of the previous year implies a deeper and eastward-shifted Aluetian Low which is typical of a positive Pacific North American Pattern (PNA). A positive PNA is frequently associated with the final year of warm ENSO conditions (Horel and Wallace 1981) and therefore, a return to cooler conditions in the eastern tropical Pacific during the following year. Cool ENSO conditions provide a favorable environment for the development of October tropical cyclones.

4.5 Summary of Three Independent Monthly Predictions from Monthly Analogs

Tables 11 and 12 summarize our individual monthly predictions and our monthly adjustments to these predictions. Based on jackknifed hindcast data from 1950-2000, the sum of the August, September, and October forecasts explains 79% of the variance in seasonal TC activity. Note that the sum of these three monthly predictions gives lower values of cyclone activity than our full seasonal statistical forecast and full-season analog forecasts.

Table 11: August, September and October individual monthly predictions and the whole number adjustments to these individual monthly adjustments. The monthly climatology is given in parentheses.

	Adjusted Model Prediction	**August Adjustment to**	**September Model Prediction**	**September Adjustment to**	**October Model Prediction**	**October Adjustment to**	**3 Month Sum Statistics**	**3 Month Sum of Adjusted Monthly Fcsts.**
NS	2.51 (2.76)	3	3.1 (3.4)	4	2.2 (1.7)	3	7.8	10
NSD	7.31 (11.80)	8	13.25 (21.7)	14	12.0 (9.0)	12	32.5	34
H	0.68 (1.55)	1	1.4 (2.4)	2	1.5 (1.1)	2	3.6	5
HD	3.81 (5.67)	4	6.00 (12.3)	6	5.9 (4.4)	6	15.7	16
IH	0.63 (0.57)	1	0.3 (1.3)	1	0.4 (0.3)	0	1.3	2.0
IHD	0.42 (1.18)	0.5	1.25 (3.0)	1.25	1.1 (0.8)	0	2.8	1.75
NTC	17.9 (26.1)	22	28.7 (48)	33	23 (18)	19	69.6	74

Table 12: Summary of 2003 seasonal Atlantic basin tropical cyclone activity based on individual monthly statistical forecasts and pre-1 August observations. We assume one named storm and three named storm days in November.

	Observed Before 1 Aug.	Seasonal Total from Monthly Statistics	Seasonal Total from Adjusted Monthly Values	Adjusted Full Seasonal Forecast
NS	4	11.8	14	14
NSD	15	47.5	49	60
H	2	5.6	7	8
HD	1.5	17.2	17.5	25
IH	0	1.3	2	3
IHD	0	2.8	1.75	5
NTC	18	88	92	120

4.6 Individual Monthly Analog Years for 2003.

Table 13 lists the hurricane activity prior to 1 August and our individual month analog years to 2003. Note that our individual monthly analogs also call for an inactive August and September season.

Table 13: Individual month analog years to 2003.

PRE 1 AUGUST							
Year	**Named Storms** (NS)	**Named Storm Days** (NSD)	**Hurricanes** (H)	**Hurricane Days** (HD)	**Cat 3-4-5 Hurricanes** (IH)	**Cat 3-4-5 Hurricane Days** (IHD)	**Net Tropical Cyclone Activity** (NTC)
Pre-1 Aug	4	15	2	1.5	0	0	18
AUGUST ANALOG YEARS							
Year	**Named Storms** (NS)	**Named Storm Days** (NSD)	**Hurricanes** (H)	**Hurricane Days** (HD)	**Cat 3-4-5 Hurricanes** (IH)	**Cat 3-4-5 Hurricane Days** (IHD)	**Net Tropical Cyclone Activity** (NTC)
1956	1	9.25	1	8.00	1	1.00	24.7
1967	1	1.50	0	0.00	0	0	2.3
1981	2	10.75	1	0.50	0	0	10.8
1985	3	11.75	3	5.25	0	0	21.8
2001	3	11.75	0	0.00	0	0	9.5
Ave.	2.0	9.0	1.0	2.6	0.20	.25	13.8
SEPTEMBER ANALOG YEARS							
Year	**Named Storms**	**Named Storm Days**	**Hurricanes**	**Hurricane Days**	**Cat 3-4-5 Hurricanes**	**Cat 3-4-5 Hurricane Days**	**Net Tropical Cyclone Activity**

	(NS)	(NSD)	(H)	(HD)	(IH)	(IHD)	(NTC)
1956	4	13	1	1.5	0	0	15.2
1968	2	6	0	0	0	0	5.5
1974	4	22.5	2	10.5	1	2.75	43.8
1985	3	16.25	1	8.0	2	3	43.5
1992	4	22.5	2	9.5	0	0	26.7
Ave.	3.4	16.1	1.2	5.9	0.60	1.15	26.9
OCTOBER ANALOG YEARS							
	(NS)	(NSD)	(H)	(HD)	(IH)	(IHD)	(NTC)
1952	2	11.25	2	6	1	1	27.6
1953	4	12.75	1	0.75	0	0	14.6
1959	2	13	1	9.25	1	2.75	33.3
1981	1	3.25	0	0.25	0	0	3.0
1999	3	13.5	2	6.25	0	0	19.6
Ave.	2.4	10.8	1.2	4.5	0.40	0.75	19.6
THREE MONTHLY ANALOG TOTALS							
	(NS)	(NSD)	(H)	(HD)	(IH)	(IHD)	(NTC)
3 Month Totals	7.8	35.9	3.4	12.9	1.2	2.15	60.3
Seasonal Totals	12.8	53.9	5.4	14.4	1.2	2.15	78.3
Actual Forecast	14	60	8	25	3	5	120

5 Forecast Adjustments

Table 14 provides a comparison of all of our forecast techniques along with the final full season adjusted forecast. Given the current (July) global conditions and other information we have, we anticipate somewhat greater activity than indicated by the sum of our individual monthly predictions. Although we give great credence to the sum of our individual monthly predictors and consider this our most skillful forecast, we feel we cannot totally disregard our prior seasonal forecasts of 6 December, 4 April, and 30 May and our seasonal analog years which indicated a more active season. We are thus making a downward adjustment of our earlier seasonal forecast and an upward adjustment to the sum of the monthly forecasts.

Table 14: Summary of all forecasts for activity after 1 August. Our entire seasonal forecast is given in the far right column.

	Original fcst scheme (1993)	**More recent fcst scheme (1998)**	**Sum of 3-month analogs**	**Sum of 3-month Statistical forecasts**	**Adjusted 1 August Forecast w/Nov.**	**Total Seasonal fcst with prior to 1 Aug. data**

NS	7.5	8.9	8.8	7.8	10	14
NSD	38.2	45.5	35.9	32.5	45	60
H	4.6	5.5	3.4	3.6	6	8
HD	19.1	22.8	12.9	15.7	23.5	25
IH	1.8	2.1	1.2	1.3	3.0	3.0
IHD	3.9	4.6	2.2	2.8	5.0	5.0
HDP	57	68	43.8	53	80	80
NTC	78	93	60.3	69.6	102	120

6 Discussion

Our data analyses through July indicates that the hurricane season in 2003 will be only slightly above average. Although we have experienced a very active early season (4NS, 2H, 15NSD), the sum of our new individual monthly forecasts from August onward indicates that the remainder of the hurricane season will have only average activity. We now believe that the 2003 season will not be as active as we had anticipated in our earlier 6 December, 4 April, and 30 May forecasts.

There has been a significant and unexpected change in the global atmospheric circulation between June and July. These changes can only partly be attributed to variations in the 40-50 day Madden-Julian Oscillation (MJO). A number of global circulation features have become less conducive to after 1 August Atlantic hurricane activity. These suppressing influences include:

1. A rise in Atlantic surface pressure and of the global pressure and height fields through the whole equatorial tropics.

2. Hurricane suppressing changes in higher latitude wind and height patterns in the Pacific and Atlantic.

3. A discontinuance of the ENSO cooling pattern in the equatorial Eastern Pacific. Water temperatures have actually warmed between June and July.

4. Development of a number of other smaller suppressing global influences to our individual monthly forecasts of August and September.

When these new data fields through July are factored into our recently developed (Blake 2002, Klotzbach 2002) individual monthly forecasts of August-only and September-only hurricane activity, we find that the sum of our new monthly models predicts below average hurricane activity for both August and for September. This is significant because, on a climatological basis, August and September account for 73 percent of all yearly activity. Our October-only forecast is for somewhat above-normal hurricane activity, however.

Overall, we see the remainder (1 August onward) of the hurricane season as having only average activity, with 10 named storms, 6 hurricanes, and 3 major hurricanes. This represents a compromise between the sum of our individual monthly forecasts and, our prior seasonal analogs.

The active hurricane season we have had so far should not be taken as an indication of heightened activity for the remainder of the season. Prior year statistics show no relationship between early season (June-July) and later season (August-November) TC activity.

We believe we are in an active multi-decadal era for Atlantic basin tropical cyclone activity; similar to the 1930s through the 1960s. The change to this new era occurred between 1994 and 1995. Except for the El Niño years of 1997 and 2002, the other six hurricane seasons since 1994 have been very active indeed. NTC activity has averaged 177 percent of the average season between 1950-2000. During the period of 1970-1994, annual Atlantic basin NTC activity averaged only 42 percent of the average annual activity of the six non-El Niño years since 1995. It is well known that some hurricane seasons during active multi-decadal period may be below average while active seasons can occur during inactive periods.

This has been an especially difficult forecast because June-July activity was greater than we anticipated and our individual monthly August and September predictions indicated activity well below what we expected from our earlier full season predictors. To rectify these differences we have decided to make an upward adjustment in the sum of our individual monthly predictions and a downward adjustment in our full season prediction.

7 Landfall Probabilities for 2003

A significant focus of our recent research involves developing forecasts of the probability of hurricane landfall along the U.S. coastline. Although individual hurricane landfall events cannot be accurately forecast months in advance, the total seasonal probability of landfall can be forecast with statistical skill. Statistically, landfall is a function of varying climate conditions. A probability specification has been developed through statistical analyses of all U.S. hurricane and named storm landfall events during the last century (1900-1999). Specific landfall probabilities can be given for all cyclone intensity classes for a set of distinct U.S. coastal regions.

Figure 5 provides a flow diagram showing how these forecasts are made. Net landfall probability is linked to the overall Atlantic basin Net Tropical Cyclone activity (NTC; see Table 15) and to climate trends linked to multi-decadal variations of the Atlantic Ocean thermohaline circulation. The thermohaline circulation is inferred from recent past years of North Atlantic sea surface temperature anomalies (SSTA*). SSTA* is expressed in units of hundredth (10^{02}) of a ˚C for the ocean location of (50-60˚N, 10-50˚W) over the last six years with primary weight given to the most recent year.

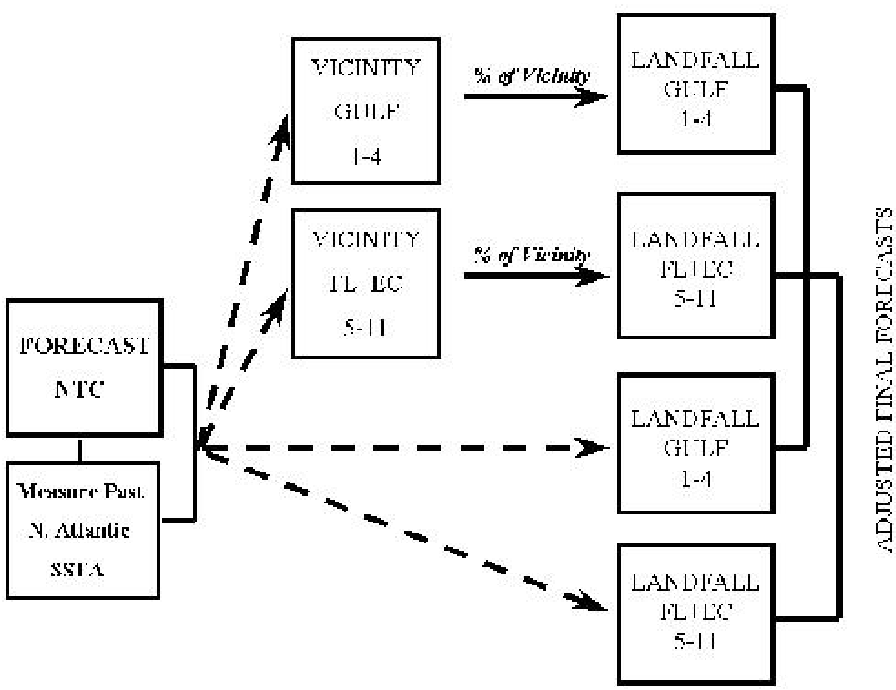

Figure 5: Flow diagram illustrating how forecasts of U.S. hurricane landfall probabilities are made. Forecast NTC values and an observed measure of recent North Atlantic (50-60°N, 10-50°W) SSTA* are used to develop regression equations for U.S. hurricane landfall. Separate equations are derived for the Gulf and for Florida and the East Coast (FL+EC).

Greater values of SSTA* indicate a stronger thermohaline circulation and higher amounts of Atlantic hurricane activity, especially for intense hurricanes. Atlantic basin NTC can be skillfully hindcast and the strength of the Atlantic Ocean thermohaline circulation can be inferred from SSTA*. The current (July 2003) value of SSTA* is 30, or 0.30°C. Hence, with a prediction of NTC of 120 for 2003, the combination of NTC + SSTA* of (120 + 30) yields a value of 150. If NTC + SSTA* were averaged over 50 to 100 years, its value would be 100. Regression equations have been developed to relate the seasonal value of NTC+SSTA* to U.S. landfall probability during the last 100 years.

As shown in Table 15, NTC is a combined measure of the year-to-year mean of six indices of hurricane activity, each expressed as a percentage difference from the long-term average. Whereas many active Atlantic hurricane seasons feature no landfalling hurricanes, some inactive years have experienced one or more landfalling hurricanes. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of U.S. hurricane landfall. For example, landfall observations during the last 100 years show that a greater number of intense (Saffir-Simpson category 3-4-5) hurricanes strike the Florida and U.S. East Coast during years of (1) increased NTC and (2) above-average North Atlantic SSTA* conditions.

Table 15: NTC activity in any year consists of the seasonal total of the following six parameters expressed in terms of their long-term averages. A season with 10 NS, 50 NSD, 6 H, 25 HD, 3 IH, and 5 IHD would then be the sum of the following ratios: 10/9.6 = 104, 50/49.1 = 102, 6/5.9 = 102, 25/24.5 = 102, 3/2.3 = 130, 5/5.0 = 100, divided by six, yielding an NTC of 107.

	1950-2000 Average	
1)	Named Storms (NS)	9.6
2)	Named Storm Days (NSD)	49.1
3)	Hurricanes (H)	5.9
4)	Hurricane Days (HD)	24.5
5)	Intense Hurricanes (IH)	2.3
6)	Intense Hurricane Days (IHD)	5.0

Table 16 lists strike probabilities for different TC categories for the entire U.S. coastline, for the Gulf Coast, Florida and the East Coast for 2003. The mean annual probability of one or more landfalling systems is given in parentheses. Note that Atlantic basin NTC activity (120) in 2003 is expected to be greater than the long-term average (100), and North Atlantic SSTA* values are measured to be above the long term average of 0. U.S. hurricane landfall probability is thus expected to be above average, owing to both a higher NTC and above-average North Atlantic SSTAs. During periods of positive North Atlantic SSTA*, a higher percentage of Atlantic basin major hurricanes cross the Florida and eastern U.S. coastline for a given level of NTC.

Table 16: Estimated probability (expressed in percent) of one or more U.S. landfalling tropical storms (TS), category 1-2 hurricanes (HUR), category 3-4-5 hurricanes, total hurricanes and named storms along the entire U.S. coast, along the Gulf Coast (region 1-4), and along the Florida and East Coast (Regions 5-11) for 2003. The long-term mean annual probability of one or more landfalling systems during the last 100 years is given in parentheses.

Coastal Region	TS	Category 1-2 HUR	Category 3-4-5 HUR	All HUR	Named Storms
Entire U.S. (Regions 1-11)	84% (80)	75% (68)	63% (52)	91% (84)	98% (97)
Gulf Coast (Regions 1-4)	64% (59)	48% (42)	36% (30)	67% (61)	88% (83)
Florida plus East Coast (5-11)	55% (51)	53% (45)	43% (31)	74% (62)	88% (81)

8 The 1995-2002 Upswing in Atlantic Hurricanes and Global Warming

Various groups and individuals have suggested that the recent large upswing in Atlantic hurricane activity (since 1995) may be in some way related to the effects of increased man-made greenhouse gases such as carbon dioxide (CO_2). There is no reasonable scientific way that such an interpretation of this recent upward shift in Atlantic hurricane activity can be made. Please see our recent 21 November 2002 verification report for more discussion on this subject.

[http://tropical.atmos.colostate.edu/forecasts/index.html]

9 Forecast Theory and Cautionary Note

Our forecasts are based on the premise that those global oceanic and atmospheric conditions which preceded comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons. It is important that the reader appreciate that these seasonal forecasts are based on statistical schemes which, owing to their intrinsically probabilistic nature, will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most U.S. coastal areas will not feel the effects of a hurricane no matter how active the individual season is. However, it must also be emphasized that a low landfall probability does not ensure that hurricanes will not come ashore. Regardless of how active the 2003 hurricane season is, a finite probability always exists that one or more hurricanes may strike along the U.S. coastline or the Caribbean Basin.

10 Forthcoming Update Forecasts of 2003 Hurricane Activity

We will be issuing further seasonal updates of our 2003 Atlantic basin hurricane activity forecast on Wednesday 3 September and for October-only activity on Thursday 2 October. All these forecasts will be available at our web address given on the front cover (http://tropical.atmos.colostate.edu/forecasts/index.html). A complete 2003 seasonal forecast verification will be issued in late November. Our initial extended range forecast for the 2004 season will be issued on 5 December 2003.

11 Acknowledgments

Eric Blake has made many important contributions to the conceptual and scientific background for this forecast. He has been a very valuable member of our forecast team. The authors are also indebted to a number of meteorological experts who have furnished us with the data necessary to make these forecasts or who have given us valuable assessments of the current state of global atmospheric and oceanic conditions. We are particularly grateful to John Knaff, Todd Kimberlain, Paul Mielke, and Ken Berry for extensive statistical analysis and advice over the past 15 years. We thank Arthur Douglas, Richard Larsen, Ray Zehr and Mark DeMaria for very valuable climate discussions and input data. In addition, Barbara Brumit and Amie Hedstrom have provided excellent manuscript, graphical, and data analysis assistance. We have profited over the years from many indepth discussions with most of the current NHC hurricane forecasters. These include Lixion Avila, Miles Lawrence, Richard Pasch, Jack Beven, James Franklin and Stacy Stewart. The first author would further like to acknowledge the encouragement he has received for this type of forecasting research application from Neil Frank, Robert Sheets, Robert Burpee and Jerry Jarrell, former directors of the National Hurricane Center (NHC), and from the current director, Max Mayfield. We also thank Bill Bailey of the Insurance Information Institute for his sage advice and encouragement in these forecast endeavors.

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12 Citations and Additional Reading

13 Verification of Previous Forecasts

Table 18: Summary verification of the authors' four previous years of seasonal forecasts of Atlantic TC activity between 1999-2002. Verification of our earlier year forecasts for the years 1984-1998 are given in our late November seasonal verifications (on this Web location).

1999	**5 Dec 1998**	**Update 7 April**	**Update 4 June**	**Update 6 August**	**Obs.**
No. of Hurricanes	9	9	9	9	8
No. of Named Storms	14	14	14	14	12
No. of Hurricane Days	40	40	40	40	43
No. of Named Storm Days	65	65	75	75	77
Hurr. Destruction Potential(HDP)	130	130	130	130	145
Major Hurricanes (Cat. 3-4-5)	4	4	4	4	5
Major Hurr. Days	10	10	10	10	15
Net Trop. Cyclone (NTC) Activity	160	160	160	160	193

2000	**8 Dec 1999**	**Update 7 April**	**Update 7 June**	**Update 4 August**	**Obs.**
No. of Hurricanes	7	7	8	7	8
No. of Named Storms	11	11	12	11	14

No. of Hurricane Days	25	25	35	30	32
No. of Named Storm Days	55	55	65	55	66
Hurr. Destruction Potential(HDP)	85	85	100	90	85
Major Hurricanes (Cat. 3-4-5)	3	3	4	3	3
Major Hurr. Days	6	6	8	6	5.25
Net Trop. Cyclone (NTC) Activity	125	125	160	130	134

2001	**7 Dec 2000**	**Update 6 April**	**Update 7 June**	**Update 7 August**	**Obs.**
No. of Hurricanes	5	6	7	7	9
No. of Named Storms	9	10	12	12	15
No. of Hurricane Days	20	25	30	30	27
No. of Named Storm Days	45	50	60	60	63
Hurr. Destruction Potential(HDP)	65	65	75	75	71
Major Hurricanes (Cat. 3-4-5)	2	2	3	3	4
Major Hurr. Days	4	4	5	5	5
Net Trop. Cyclone (NTC) Activity	90	100	120	120	142

2002	**7 Dec 2001**	**Update 5 April**	**Update 31 May**	**Update 7 August**	**Update 2 Sept**	**Obs.**
No. of Hurricanes	8	7	6	4	3	4
No. of Named Storms	13	12	11	9	8	12
No. of Hurricane Days	35	30	25	12	10	11
No. of Named Storm Days	70	65	55	35	25	54
Hurr. Destruction Potential(HDP)	90	85	75	35	25	31
Major Hurricanes (Cat. 3-4-5)	4	3	2	1	1	2
Major Hurr. Days	7	6	5	2	2	2.5
Net Trop. Cyclone (NTC) Activity	140	125	100	60	45	80

Footnotes:

[1]Professor of Atmospheric Science

[2]Research Associate

[3]Dr. Landsea, a former project member, is an employee of the NOAA Atlantic Oceanographic and Meteorological Laboratory. As part of his research to improve NOAA's climate forecasting ability, he collaborates with researchers at Colorado State University on the CSU seasonal hurricane forecasts (see page 3).

[4]Research Associate

[5]Research Associate

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